Letters to the Editor

Indian J. Phys. **44**, 511–513 (1970).

Reliability of anode as a reference point of probe potentials in dc gas discharge

BY D. R. GUPTA AND G. L. GUPTA

Department of Physics, University of Jodhpur, Jodhpur

(*Received* 17 *November* 1970)

Langmuir (1923) developed the theory for a plane probe (it can as well be applied to a cylindrical probe) and he used it for the study of the plasma of gas discharge (SPM). When the probe is given sufficiently negative potential the electron current to the probe (i_p) under a retarding potential V_0, i.e. $(V-V_s)$, across the positive ion sheath is given by

$$= i_0 e^{\frac{-eV_0}{kT_e}} = i_0 e^{\frac{-e(V-V_s)}{kT_e}} \tag{1}$$

where i_0 is the random plasma electron current to the probe, V the probe potential. V_s the plasma potential at the point, k the Boltzmann's constant, e the electronic charge and T_e the electron temperature in degrees absolute. Hence, we have

$$\log_{10} i_p = \text{constant} - \frac{eV}{kT_e} \tag{2}$$

Thus, the semi-logarithmic plot of electron current (i_p) *vs* probe voltage (V) is a straight line; the temperature T_e of the electrons in the plasma may be determined from the slope, $e/k\,T_e$ of this line. But in practice the probe voltage is generally referred to one of the electrodes of dc discharge tube (usually the anode which could be called the reference electrode).

The position is entirely different in the case of hf discharges The electrodes cannot be used as references in view of their alternating potentials Moreover, external electrodes are used for exciting the discharge. Thus in order to use probe method in hf discharges, it is necessary to introduce an additional electrode, anti-probe (A_p) as termed by Beck (1935). Beck and others (1952) have recommended that an anti-probe with large collecting area be used to enable study of broad spectrum of electron velocities.

Johnson & Malter (1950) have described a 'double probe' method (DPM) which is very similar to the use of an extra electrode as the anti-probe for hf discharge. The method has been amply used by Kojima (1953) and others for the study of hf discharges. From the theory of the double probe method we get,

$$\log_e\left[\frac{\Sigma I}{i_p}-1\right] = -\phi V_d + \log_e\left[\frac{i_{0A}}{i_{0P}}\,\epsilon^{\phi V_c}\right] \quad \dots \quad (3)$$

putting $\quad \Gamma = \frac{\Sigma I}{i_p} - 1 \quad$ and $\quad \sigma = \frac{i_{0A}}{i_{0P}}\,\epsilon^{\phi V_c}$

we have,

$$\log_{10}\Gamma = -\phi V_d + \log_{10}\sigma \quad (4)$$

where ΣI is the total positive ion current to the probe system, ϕ is $e/k.T_e$, V_d the differential voltage applied to the system, V_c the difference in potentials between the plasmas surrounding P and A_p, i_p the electron current received by the probe Thus the plot of $\log_{10}\Gamma$ against V_d is a straight line whose slope is $e/k.T_e$ from which the electron temperature can be determined.

Experiments have been carried by Gupta (1956) in dc plasma of neon gas in the pressure range of 3.6 to 67×10^{-2} mm Hg using a tungsten wire probe of length 3 45 cm and diameter 0.22mm. Observations are recorded for probe currents (i) by varying proble voltage (V) for different values of discharge currents and voltages A sample characteristic is shown in figure 1 for the gas pressure

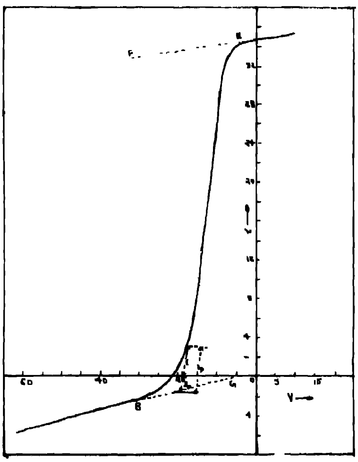

Figure 1. Graph showing probe potential V *vs* probe current i_p.

0.096mm with discharge current of 50mA and voltage 50V. The electron current i_p to the probe at probe potential V is determined by adding the value of I_p (positive ion current to the probe as read from extrapolated line BG) to the actual value of probe current i_p at the corresponding voltage. Figure 2(a) shows the corresponding sample plot of $\log_{10} i_p - V$ curve which is fairly linear but bends near -13.5V giving the value of the space potential. From the slope of the line the electron temperature T_e has been calculated and found to be 45,000°K.

Now we apply DPM theory to our system considering the anode as anti-probe of the double probe system. The values of total positive ion current to the probe system, ΣI for different values of probe voltages are found from figure 1 by reading the total current between the extrapolated lines BG and EF, which is actually equal to the sum of I_p and I_A positive ion current to the probe and the anode current, respectively. The corresponding values of $\log_{10}(\Sigma I/i_p - 1)$ are computed and the plot is made for $\log_{10} T - V$ as shown in figure 2(b) which is mostly linear without any bend in a comparatively wider voltage range in contrast to figure 2(a). The electron temperature T_e is calculated from the slope of this line and found to be 42,000°K.

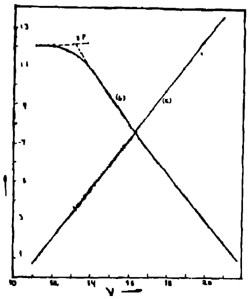

Figure 2. (a) Graph showing probe potential V *vs* $\log_{10} i_p$
(b) Graph showing probe potential V *vs* $\log_{10} T_e$

The values of electron temperature T_e found by two different approaches (SPM and DPM theories) of analysis of $i-V$ curves for dc gas discharge are found to agree well. Hence it can be said that the anode has served as a true reference point in dc discharge and the double probe technique could be used for analysis of dc discharge also. Further this technique enables the use of greater portion of $i-V$ curve for analysis of electrons of wider velocity range to furnish parameters of dc gas discharge.

References

Beck 1935 *Zeit. f. Physik.* **79**, 355.
Gupta G. L. 1956 *Raj. Univ. Phys. Sc. Studies*, I & II, 34 and 51.
Johnson & Malter 1950 *Phys. Rev.* **80**, 58
Kojima, Takayama & Shimauchi 1953 *Phys. Soc. Japan* **8**, 55.
Langmuir & Mott-Smith 1923 *Gen. Elec. Rev.* **26**, 731.
Mehta G. K. 1952 *Thesis, Univ. of Bombay.*